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Industrial Hygiene Survey Report
of
DEFENSE FUEL SUPPORT POINT
4820 River Road
Cincinnati, Ohio 45233

Survey Conducted By:
Greg Piacitelli, C.I.H., Industrial Hygienist (NIOSH)
David Votaw, Toxicologist (NIOSH)
Radha Krishnan, P.E., Project Director (PEI)

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Report Written by:
Greg Piacitelli, NIOSH
Radha Krishnan, PEI

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16. Abstract (Limit: 200 words) As part of a study of worker exposure, personal protective equipment, and engineering controls in use in work areas where exposure to ethylene glycol ethers is possible, an industrial hygiene survey was conducted at the Defense Fuel Support Point (SIC-4231), Cincinnati, Ohio. The site has been operational since 1953, occupying an area of 45 acres. The activities include receiving, storing, and distributing of jet fuel for military use. At this site 2-methoxyethanol (109864) (2-ME) was added as an icing inhibitor to one of the jet fuels. JP-4 contained 0.10 to 0.15 weight percent of 2-ME and JP-5 contained diethylene-glycol-monomethyl-ether (111773) (DEGME) at a concentration of 0.15 to 0.20 weight percent received at this location for shipment elsewhere. The potential existed for inhalation and dermal exposure to 2-ME. Exposure controls included the use of engineering controls at the truck loading operation and quality control analysis divisions as well as the wearing of personal protective equipment. The monitoring results indicated that full shift inhalation exposures to 2-ME were low, less than 0.34 part per million (ppm). Short term exposures occasionally reached 6.86ppm. Due to the small number of workers with a potential of exposure to glygol ethers, the authors recommend that this facility should not be included in additional health studies. The authors recommend that modification of work practices and ventilation equipment would help keep exposure levels down in the quality control laboratory and that individuals wear personal protective equipment suitable for inhalation and dermal exposures.

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PURPOSE OF SURVEY:	To evaluate worker exposures, personal protection equipment and engineering controls in work areas using any of four ethylene glycol ethers (2-ME, 2-MEA, 2-EE, 2-EEA) proposed for revised regulation by OSHA. This information will be used to assess the feasibility of any additional health studies of glycol ether-exposed workers.
EMPLOYER REPRESENTATIVES CONTACTED:	William D. Evans, Quality Surveillance Representative, Defense Fuel Supply Center Gene Garner, Terminal Superintendent, Gulf Interstate Energy Inc.
EMPLOYEE REPRESENTATIVES CONTACTED:	Mark Gronauer, Teamsters Local Union No. 114
SIC Code:	4231 (Fuel Distribution)

ABSTRACT

The National Institute for Occupational Safety and Health (NIOSH) is conducting a study entitled "An Exposure Assessment of Industries Using Ethylene Glycol Ethers" in collaboration with PEI Associates, Inc. (PEI), Cincinnati, Ohio. This work is being conducted to determine the extent of occupational exposure to these compounds and to assess the feasibility of any additional health studies of glycol ether-exposed workers. In addition, the Occupational Safety and Health Administration (OSHA) is interested in this information because they are proposing to revise their current regulations for 2-methoxyethanol, 2-ethoxyethanol, and their respective acetates.

The NIOSH study involves surveying several workplaces where these glycol ethers are manufactured or used as ingredients in process materials. Each survey involves collecting industrial hygiene samples and obtaining information concerning glycol ether usage, process operations, and engineering controls, past exposure levels, the size of the potentially exposed workforce, and the corporate industrial hygiene and safety programs. This information is being compiled by PEI and reported to OSHA's Office of Regulatory Analysis for its assessment of the technical feasibility and economic impact of revising the exposure standards for the glycol ethers.

The specific results from a survey conducted at the Defense Fuel Support Point jet fuel distribution terminal in Cincinnati, Ohio are presented in this report. At this facility, an ethylene glycol ether (2-methoxyethanol), added as an icing inhibitor, is a minor component of one of the jet fuels (JP-4) handled. Therefore, the potential exists for inhalation and dermal exposure to 2-methoxyethanol (2-ME).

The monitoring results indicate that full-shift inhalation exposures to 2-ME were low (less than 0.34 ppm). Higher short-term exposures, however, were measured during periodic activities including a concentration of 6.86 ppm. The long-term exposures were relatively low when compared to the 25 ppm OSHA PEL, the 5 ppm ACGIH TLV, and the "lowest feasible level" NIOSH REL.

Although measureable exposures to 2-ME occurred during the survey, this work group would not appear to well-suited for future occupational health studies of glycol ether-exposed workers because of the small number of potentially exposed workers at this facility.

INTRODUCTION

Adverse central nervous system (encephalopathy) and hematotoxic (anemia, leukopenia) effects in workers exposed to 2-methoxyethanol (2-ME) were first noted in the late 1930s [Donley 1936; Parsons and Parsons 1938]. The hematotoxic effects of exposure to 2-ME and other ethylene glycol ethers were later confirmed in animal studies [Miller et al. 1983; Werner et al. 1943ab]. In the late 1970s, studies reported adverse reproductive effects, including testicular atrophy, infertility, fetotoxictiy, and fetal malformations in laboratory animals exposed to different ethylene glycol ethers [Doe et al. 1983; Miller et al. 1982, 1984, Brown et al. 1984].

Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs) were established for eight glycol ethers (including 2-ME (25 parts per million or ppm), 2-methoxyethyl acetate or 2-MEA (25 ppm), 2-ethoxyethanol or 2-EE (200 ppm) and 2-ethoxyethyl acetate or 2-EEA (100 ppm)) in 1981 based upon the 1968 American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs®). The TLVs® were based on the hematotoxic and neurotoxic effects and on exposure concentrations reported in the early case reports of human health effects. However, more recent information from experimental animal studies indicates that adverse reproductive effects may occur at exposure concentrations below the current OSHA PELs. Therefore, because of the increased concern about their potential to cause reproductive and embryotoxic effects, OSHA is currently developing a proposal to revise its regulation of these four glycol ethers.

Under contract to OSHA's Office of Regulatory Analysis (ORA), PEI Associates, Inc. (PEI) is assessing the technical feasibility and economic impact of revising the exposure standard for ethylene glycol ethers. This work involves compiling information concerning: glycol ether usage patterns, workplace exposures, control technology, and compliance costs. Data are being collected through both mail questionnaires and site visits.

The National Institute for Occupational Safety and Health (NIOSH) is evaluating workplace exposures by cooperatively conducting industrial hygiene surveys with PEI at approximately 11 different plants representing the major usage groups (e.g., industrial coatings, jet fuel additives, commercial printing, aircraft painting, automobile refinishing, maintenance painting, and electronics manufacture) of the four regulated glycol ethers. Each survey involves industrial hygiene sampling and collecting information concerning process operations and engineering controls, glycol ether usage patterns, the size of the potentially exposed workforce, and exposure control methods. NIOSH intends to use this information to determine the feasibility of conducting any additional health studies of glycol ether-exposed workers.

This report presents the results of a site visit conducted at the Defense Fuel Support Point (DFSP) jet fuel terminal during June 28-30, 1988.

BACKGROUND

Physical and Chemical Properties. The glycol ethers 2-methoxyethanol and 2-ethoxyethanol, and their respective acetates, are part of the family of ethylene glycol ethers; their chemical and physical properties are summarized in Table 1. The ethylene glycol ethers are manufactured by the reaction of ethylene oxide with the appropriate alcohol (e.g., ethanol, methanol); the glycol ethers are used to form acetates by their reaction with acetic acid. In general, glycol ethers and their acetates are colorless liquids with versatile solvent properties (e.g., miscible in water and most hydrocarbon solvents, low vapor pressure, slow evaporation rate) which make them useful in a wide variety of industrial applications.

Production, Use, and Exposure. The total U.S. production of the regulated ethylene glycol ethers and acetates in 1983 is listed in Table 2.

Ethylene glycol ethers and acetates have been used commercially for over 50 years, primarily as solvents in the manufacture of protective coatings such as paints, lacquers, metal coatings, baking enamels, phenolic varnishes, epoxy resin coatings, and stains [NIOSH 1983]. Ethylene glycol ethers and acetates are also used as solvents for printing inks, textile dyes and pigments, and leather finishes; as anti-icing additives in military jet fuels; and in the manufacture of printed circuit boards. Many of these uses require direct handling of the glycol ethers by workers during the formulation and/or evaporation stages, thus leading to the potential for occupational exposure via inhalation and/or skin absorption [Dugard et al. 1984]. Based on data obtained during the National Occupational Hazard Survey (NOHS) conducted by NIOSH during 1972-1974, an estimated 2.5 million men and women may be occupationally exposed to glycol ethers (NIOSH 1977). The numbers of workers potentially exposed to the regulated glycol ethers are presented in Table 3.

Toxicology. The effects of the short-chain ethylene glycol ethers (2-ME, 2-MEA, 2-EE, and 2-EEA) on reproduction and fetal development have been studied extensively in rats, rabbits, and mice. The results uniformly show developmental toxicity, including increased incidences of fetal malformations and resorptions. In general, the evidence suggests that the glycol ether acetates have the same toxicologic activity as their parent glycol ethers. Some studies have indicated that behavioral teratogenic effects may occur in the offspring of rats treated with 2-ME and 2-EE [Nelson and Brightwell 1984]. Testicular damage has also been caused in rats after acute exposures to 2-ME [Doe et al. 1983].

Changes in the blood and adverse effects on the bone marrow and thymus have been observed in rats, mice, and rabbits exposed to 2-ME. The effects of lowered red and white blood cell counts appear to be the result of bone marrow suppression. Recent studies [Miller et al. 1983a] have confirmed histologically the reported depressant effect of 2-ME on the bone marrow and thymus of rats and rabbits. Grant et al. [1985] have reported at least partial reversal of these effects in rats following short-term exposure to 2-ME. Limited information suggests that 2-EE, 2-EEA, and 2-MEA also produce adverse effects in the peripheral blood of rats [Werner et al. 1943b], mice [Nagano et al. 1979], and dogs [Werner et al. 1943a].

TABLE 1

PHYSICAL AND CHEMICAL PROPERTIES OF FOUR ETHYLENE GLYCOL ETHERS

Property	2-ME	2-MEA	2-EE	2-EEA
IUPAC Chemical Name	2-methoxyethanol	2-methoxyethyl acetate	2-ethoxyethanol	2-ethoxyethyl acetate
CAS No.	109-86-4	110-49-6	110-80-5	111-15-9
RTECS No.	KL5775000	KL5950000	KK8050000	KK8225000
Empirical formula	$C_3H_8O_2$	$C_5H_{10}O_3$	$C_4H_{10}O_2$	$C_6H_{12}O_3$
Molecular weight	76.1	118.1	90.1	132.1
Specific gravity	0.97	1.01	0.93	0.97
Density (lbs/gal)	8.04	8.37	7.75	8.10
Vapor pressure (mmHg) 25°C	9.7	2.0-3.7	5.7	2.8
20°C	6.0	2.0	4.0	2.0
Boiling point (°C)	124.5	145.0	135.0	156.0
Flash point (°F) open cup	115	140	120	138
1 ppm=mg/m3 (25°C,760mmHg)	3.11	4.83	3.69	5.41
1 mg/m3=ppm (25°C,760mmHg)	0.32	0.21	0.27	0.19
Other identifiers:	methyl cellosolve ethylene glycol monomethyl ether Dowanol EM	methyl cellosolve acetate ethylene glycol monomethyl ether acetate	cellosolve ethylene glycol monoethyl ether Dowanol EE	cellosolve acetate ethylene glycol monoethyl ether acetate

Clayton and Clayton, 1982

TABLE 2

U.S. PRODUCTION OF FOUR ETHYLENE GLYCOL ETHERS

Compound	1983 Production (pounds)
2-ME	83,000,000
2-MEA	1,000,000
2-EE	187,000,000
2-EEA	153,000,000

SRI 1984

TABLE 3

ESTIMATE OF U.S. WORKERS POTENTIALLY EXPOSED TO ETHYLENE GLYCOL ETHERS AND ACETATES

Compound	Number of Workers
2-ME	100,000
2-MEA	20,500
2-EE	407,000
2-EEA	321,000

NIOSH 1977

Methoxyacetic acid (MAA) has been isolated and identified in urine as the major metabolite of 2-ME in rats [Miller et al. 1983]. Although all of the glycol ethers are not metabolized via a single pathway, it has been suggested that the major metabolites of 2-ME and 2-EE, MAA and ethyoxyacetic acid (EAA), respectively, act to cause the testicular [Miller, et al., 1982, 1984], developmental [Brown et al. 1984], and hematotoxic [Miller et al. 1982] effects observed in rats treated with 2-ME or 2-EE.

Neurologic and hematologic effects were observed in workers following inhalation and dermal exposure to 2-ME [Donley 1936; Greenburg et al. 1937; Zavon 1963; Ohi and Wegman 1978]. A cross-sectional study assessing fertility among men engaged in the production of 2-ME reported decreases in testicular size; no quantitative estimates of exposure concentrations were provided [Cook et al. 1982]. A cross-sectional evaluation of semen quality among men exposed to 2-EE (concentrations ranged from zero to 23.8 ppm 2-EE) found significantly lower sperm count per ejaculate [NIOSH 1986]. Painters exposed to both 2-EE and 2-ME (full-shift exposure concentrations of 2-EE averaged 15 ppm; the concentration of 2-ME was not mentioned) had sperm abnormalities including reduced sperm counts, and abnormalities of both red and white blood cells [Welch and Schrader 1986].

APPLICABLE STANDARDS AND RECOMMENDED LIMITS

Based on toxicological data, NIOSH recommended in Current Intelligence Bulletin (CIB) No. 39 <u>The Glycol Ethers, with Particular Reference to 2-Methoxyethanol and 2-Ethoxyethanol: Evidence of Adverse Reproductive Effects</u> that 2-ME, 2-EE, and structurally related glycol ethers be regarded in the workplace as having the potential to cause adverse reproductive effects in male and female workers. Also noted were and embryotoxic effects, including teratogenesis, in the offspring of the exposed pregnant females [NIOSH 1983]. The NIOSH current recommended exposure limit (REL) is therefore "reduction of workplace levels to the lowest extent possible." Since publication of

CIB No. 39, additional data on the glycol ether compounds have been published (as summarized in ECETOC 1985). These data are currently being evaluated during the development of a criteria document for the ethylene glycol ethers.

The current NIOSH RELs, OSHA PELs and ACGIH TLVs® established for the targeted glycol ethers are summarized in Table 4.

TABLE 4

APPLICABLE STANDARDS AND RECOMMENDED LIMITS

Compound	Exposure Limit[a] (ppm) NIOSH REL	OSHA PEL	ACGIH TLV®
2-ME	*	25[s]	5[s]
2-MEA	*	25[s]	5[s]
2-EE	*	200[s]	5[s]
2-EEA	*	100[s]	5[s]

CFR 1984; ACGIH 1987

[a] 8-hour time-weighted-average (TWA_8)
[s] Skin notation
* Reduce exposure to lowest feasible level

HISTORY AND DESCRIPTION OF THE FACILITY

The Defense Fuel Support Point (DFSP) fuel distribution terminal in Cincinnati, owned by the Department of Defense, has been operating since 1953 and occupies an area of 45 acres. The activities conducted at the terminal include receiving, storage, and distribution of jet fuel for military use. The terminal is operated under a three-year contract by a private contractor; Gulf Interstate Energy Inc. is the present operator.

PROCESS DESCRIPTION

Two military aviation jet fuels are handled at the terminal: JP-4 and JP-5. The JP-4 jet fuel, which is used by the Air Force, contains 0.10 to 0.15 weight percent of 2-methoxyethanol (2-ME) as a fuel system icing inhibitor (FSII). The FSII in the JP-5 jet fuel (used by the Navy) is diethylene glycol monomethyl ether (DEGME), at a concentration of 0.15 to 0.20 weight percent.

The jet fuels, already blended with the appropriate FSII, arrive at the DFSP terminal by barge (20,000 barrel capacity) approximately every two weeks. An average of 80,000 barrels of fuel are received per month; JP-4 is sent from Ashland Oil Co. in West Virginia, whereas JP-5 is shipped from the Gulf Coast areas of Texas and Louisiana. JP-4 represents approximately 85 percent of the total throughput at the DFSP terminal.

There are six 80,000-barrel tanks at the terminal for the outdoor storage of jet fuel; four of these tanks are used for JP-4 and the other two for JP-5. There is also an 8,000-gallon storage tank of 2-ME and a few 55-gallon barrels of DEGME on site. Appropriate quantities of these glycol ethers may be injected at the terminal into the JP-4 and JP-5 fuels, respectively, if the fuel received by barge does not meet the necessary FSII specifications. Gulf Interstate Inc. reported that this has occurred only once during the last two years. The FSII injection process involves opening necessary valves and pumping the necessary FSII quantity into the fuel storage tanks.

The jet fuels are loaded from the storage tanks into tanker trucks for distribution to Air Force and Navy bases and also to private contractors testing military aircraft. Approximately 150 tanker trucks, each of 9,000-gallon capacity, are loaded per week at the DFSP terminal.

DESCRIPTION OF THE WORKFORCE

The DFSP terminal operates one 10-hour shift per day, 5 days per week. There are a total of 22 Gulf Interstate Energy (contractor) employees at the terminal. Approximately ten employees have a potential for exposure to 2-ME at this facility and can be grouped into the following job classifications:

Unloading Operator. Two unloaders and one tankerman are involved in the barge unloading operations. The operators ensure that the fuel is uniformly pumped from the three compartments of the barge. The unloading operators also collect quality control (QC) samples from each of the compartments. One-quart samples are collected by dipping a container attached to a rod into the compartment; two 1-gallon composites are also collected from each barge. The entire unloading process (including QC sampling and transfer of the jet fuel from the barges to the storage tanks) takes 10 to 12 hours. Two barges (containing JP-4 fuel) were unloaded during the survey.

There is a potential for inhalation and dermal exposure to the unloading operators during the sampling of the barges. The personal protective equipment worn by the unloading operators consists of hard hats, safety shoes, and rubber gloves.

Loading Operators. There are three tanker truck loading stations located outdoors at the DFSP facility, two used for JP-4 and one for JP-5. Two tankers can be loaded simultaneously at each covered station. One-quart QC samples are collected by the loader operators from hatches at the top of each tank truck by dipping a container attached to a rod into the tanks. The loading process (including hooking and unhooking of hoses and QC sampling) takes approximately 15 minutes per tank truck. There are six loader operators employed per shift. Personal protective equipment worn by the loader operators consists of hard hats and safety shoes.

In addition to loading trucks, the loader operators also perform periodic gauging and sampling of the fuel and FSII (2-ME) tanks. The 2-ME tank is gauged on a monthly basis. The gauging operation consists of inserting a metallic tape measure from a hatch at the top of the tank; the length of wet tape is read while being rewound. The temperature of the fuel is also measured. In addition, quality control samples are dipped from the tanks at this time. This task takes only about 10-15 minutes per tank. There is potential for exposure, particularly dermal, during these operations. Hard hats and safety shoes are the only personal protective equipment used during gauging and sampling of the tanks.

Maintenance. One maintenance person is employed per shift to monitor the fuel handling equipment and to perform any necessary maintenance on pump seals, valves, and strainers. There is a potential for inhalation and dermal exposure to the maintenance person during the draining of water (which forms in the tank due to condensation) from the bottom of the fuel tank. Safety shoes are the only type of personal protective equipment worn by the facility maintenance worker.

Cleaning and heavy maintenance on the tanks were reported to occur roughly once every 5 years. The U.S Army Corps of Engineers is responsible for these operations. Respirators are reportedly worn during these operations.

Quality Surveillance Representative. The Department of Defense Quality Surveillance Representative (QSR) conducts laboratory analyses on the QC samples from the incoming barges. The quart samples are first transferred to measuring cylinders in the laboratory. Then the following types of QC tests are performed in the laboratory:

- Color
- Appearance
- Sediment Content
- API Gravity
- Flash Point
- FSII Concentration

Most of these tests are performed under a laboratory hood. No personal protective equipment is worn by the QSR when doing the analyses.

Some QC analyses are also performed by a loader operator on samples collected from tank trucks and fuel tanks. These QC checks generally consist of only visual inspection and API gravity determination and are conducted in a small shed (with open doors and windows) located in the vicinity of the truck loading stations. Hard hats and safety shoes are the only types of personal protective equipment worn by the loading operator during QC analysis. There is a potential for dermal exposure from accidental spills when transferring samples for QC analysis.

The following activities were identified by DFSP personnel as having the highest potential for short-term exposures to glycol ethers:

- Sampling/Gauging of Storage Tanks
- Sampling of Barges
- QC Analysis
- Draining of Water from Tanks

DESCRIPTION OF EXPOSURE CONTROLS

Large open-air process operations such as those at the DFSP fuel terminal incorporate a number of controls designed to prevent the release of contaminants into the environment. Many of these controls are an integral part of the process equipment, whereas others have been added for a specific purpose. Some controls are designed to reduce worker exposures, whereas others are intended to abate environmental releases. Frequently, the environmental controls also function indirectly to reduce the level of toxic contaminants in the workplace air.

DFSP personnel were interviewed to identify any controls (engineering and/or protective equipment) that directly or indirectly reduce workplace exposures to glycol ethers. These controls are presented herein by type and area/task.

A. Engineering Controls

Truck Loading Operations. A vapor recovery system was installed at the DFSP terminal in 1984 for recovery of gasoline vapors displaced during tank truck loading of JP-4 jet fuel. This system was installed in response to EPA Volatile Organic Compound (VOC) emission regulations; the vapor recovery unit, however, is also instrumental in minimizing occupational exposures to the loader operators. The installed cost of the Carbon Adsorption-Absorption Gasoline Vapor Recovery Unit was approximately $1.2 million dollars. The 15-minute throughput capacity of the vapor recovery unit is 18,000 gallons, thus permitting a maximum of two 9000-gallon JP-4 tank trucks to be loaded simultaneously. The vapor recovery system is designed for a hydrocarbon vapor concentration of 15 percent from the truck loading rack. Also, the DFSP facility has an on-site oil/water separation system for treating runoff.

Quality Control Analysis. There is a hood with local exhaust ventilation in the laboratory where QC analyses are conducted on barge samples.

B. Personal Protective Equipment

Hard hats and steel-toed safety shoes are required in the barge unloading and truck loading areas. Unloading operators wear heavy-rubber gloves during the collection of QC samples from barges. Other types of gloves, safety glasses and aprons are also available at the DFSP facility.

MEDICAL AND INDUSTRIAL HYGIENE PROGRAMS

As a DOD employee, the Quality Surveillance Representative (QSR) receives an annual medical exam which includes a blood test, EKG, and complete physical exam. The contractor employees are not covered under any DFSP-related medical program.

There is no formal industrial hygiene program at the DFSP facility. In March 1988, three 8-hour time-weighted average (TWA_8) and one 15-minute short-term personal monitoring samples were collected by the QSR at the DFSP terminal using 3M® gas monitoring badges. The TWA_8 samples were taken on a loader operator, a barge unloading operator, and the QSR; the short-term sample was taken on the QSR when conducting QC analyses. All samples showed non-detectable levels of 2-ME (the limit of detection was 0.22 ppm for the TWA_8 samples and 7.17 ppm for the 15-minute short-term sample).

SAMPLING STRATEGY AND METHODS

A sampling survey was conducted over two shifts on June 29-30, 1988, at the Defense Fuel Support Point terminal in Cincinnati, Ohio to measure the extent of exposures associated with 2-ME in the receiving, storage, and distribution of JP-4 jet fuel. Both personal and area long-term (5-9 hour) and short-term (8-18 minute) samples were collected. Long-term samples evaluated full-shift exposures whereas short-term samples measured peak exposures of relatively short duration.

Long-term samples were collected on unloading operators, the quality surveillance representative, loading operators, and the maintenance worker while performing routine daily duties. Short-term samples were collected on the QSR while running QC analyses, on a loader operator while gauging a storage tank, on a loader when conducting a QC tests at the loading station, and on the maintenance worker when draining water from a storage tank.

OSHA Method 53 [OSHA 1985] was used for sampling and analysis of all NIOSH samples. Airborne samples were collected on charcoal, desorbed with methylene chloride/methanol and analyzed by gas chromatography using flame ionization detection (GC/FID). A brief description of the sampling and analytical procedures follows:

Long-term samples were taken with Gilian Model LFS-113DC portable low-flow air sampling pumps calibrated at a flow rate between 0.1-0.2 liters per minute (Lpm). Targeted sample volumes were generally between 30-70 liters.

Short-term samples were collected with SKC Model 224 sampling pumps calibrated at approximately 1.0 Lpm; sample volumes were nominally 15 liters.

All samples were collected on SKC No. 226-01 coconut charcoal tubes (100 mg primary/50 mg backup sections) connected to sampling pumps with tygon tubing. Personal samples were attached near the breathing zone of the worker while area samples were positioned in the immediate vicinity of typical work stations. Samples were refrigerated between sample collection and analysis. Sample analyses were performed by DataChem (Salt Lake City, UT). Charcoal tube samples were desorbed with 95/5 (v/v) methylene chloride/methanol and analyzed using a Hewlett-Packard Model 5890A gas chromatograph equipped with a flame ionization detector.

Table 5 presents the analytical limit of detection (LOD) and limit of quantitation (LOQ) for the ethylene glycol ether sampled at the DFSP terminal. The LOD is that level at which an instrument response can confidently be attributed (95 percent probability) to the presence of the compound being measured; the LOQ indicates the point at which an indicated response is within acceptable confidence limits. Table 5 also shows the equivalent LOD and LOQ concentrations for an 8-hr TWA sample collected at 0.2 Lpm and a 15-minute short-term sample collected at 1.0 Lpm.

TABLE 5

LIMIT OF DETECTION (LOD) AND LIMIT OF QUANTITATION (LOQ) FOR 2-METHOXYETHANOL (2-ME)

Analytical Limits (mg/sample)		Sampling Limits (ppm/sample)			
		TWA8[a]		Peak[b]	
LOD	LOQ	LOD	LOQ	LOD	LOQ
0.01	0.03	0.03	0.10	0.21	0.64

[a] 8-hour time-weighted average sample collected at 0.2 Lpm.
[b] 15-minute short-term sample collected at 1.0 Lpm.

MONITORING RESULTS

A total of 15 field samples were collected and analyzed for 2-ME. Three of the 15 results were below the analytical limit of detection for 2-ME (0.01 milligrams per sample) and nine of the sample results were between the limit of detection and the limit of quantitation (0.03 milligrams per sample) of the analytical method. (Note that the actual sampling LODs and LODs vary according the sampling duration for each sample). Individual sample results are reported in Table 6 as time-weighted averages (TWAs) over the respective sampling duration.

Long-Term Sampling. A total of 10 long-term samples (nine personal and one area) were collected during the monitored workshifts (Table 6). Note that one sample (AF-16), classified as a long-term sample, had only a 77 minute sampling duration due to pump failure. Sample results of all nine full-shift personal samples ranged from non-detectable to 0.34 ppm; the arithmetic mean for these nine samples was 0.11 ppm. The highest concentration of 0.34 ppm was obtained on the maintenance person who had drained water for 15 minutes from a JP-4 storage tank during the sampling period. The remainder of the personal samples showed 2-ME concentrations below 0.14 ppm. The area sample collected in the QC laboratory had a concentration of 0.25 ppm 2-ME.

Short-term Sampling. Five short-term personal samples were collected to evaluate peak exposures to 2-ME; three samples were collected during QC analyses, one was collected during the draining of water from a JP-4 fuel storage tank, and one was collected during the gauging of a fuel tank. The sample results ranged from 0.21 ppm (which is below the limit of quantitation) to 6.86 ppm (arithmetic mean = 1.65 ppm). The highest sample result of 6.86 ppm was obtained on the maintenance person during draining of water from the bottom of a JP-4 fuel tank.

SUBSTITUTES

The QSR indicated that any FSII substitute for 2-ME in the JP-4 jet fuel would need to meet the MIL specifications of the Department of Defense. The QSR, however, mentioned that DEGME could theoretically be used as a FSII substitute for 2-ME in the JP-4 fuel, since it is being successfully used in the JP-5 fuel being handled at the DFSP terminal. The Department of Defense would need to apply for a waiver to the JP-4 specifications if such substitution were feasible and desirable. With respect to the Cincinnati DFSP terminal (which handles and distributes both JP-4 and JP-5 fuel), the QSR indicated that an advantage of such substitution would be that only one type of FSII (i.e., DEGME) would need to be stored on site. This would also result in lower material costs because the FSII could be purchased in larger bulk quantities.

DISCUSSION

Sampling results clearly indicate that exposures to 2-ME are occurring during routine activities at the Defense Fuel Support Point terminal. Most samples had detectable results which ranged from 0.04-0.34 ppm (long-term samples) and from 0.21-6.86 ppm (short-term samples).

Several periodic activities resulted in significant exposures to 2-ME. A concentration of 6.86 ppm was measured during the draining of water from a JP-4 fuel tank by the maintenance worker. Dermal contact with the liquid was

TABLE 6

MONITORING RESULTS FOR 2-METHOXYETHANOL (2-ME)
DEFENSE FUEL SUPPORT POINT (DFSP) FUEL DISTRIBUTION TERMINAL
CINCINNATI, OHIO

June 29-30, 1988

Date	Sample ID	Job (Activity)	Time Start-Stop	Flow (cc/min)	Duration (min)	Air volume (L)	Concentration (ppm)[a] 2-ME
06-29-88	AF-23	Unloading Operator	20:48-01:52	201.3	304	61.2	<0.05[b]
06-29-88	AF-5	Unloading Operator	20:55-06:18	202.2	563	113.8	<0.03[b]
06-29-88	AF-4	Unloading Operator	21:02-04:20	206.2	438	90.3	0.04[c]
06-29-88	AF-19	QSR (QC tests)[d]	21:21-21:39	1000.0	18	18.0	0.36[c]
06-30-88	AF-2	Loading Operator	6:05-11:45	198.9	340	67.6	0.14[c]
06-30-88	AF-16	QSR	8:26-09:43	204.9	77	15.8	<0.20[b]
06-30-88	AF-17	Loading Operator	6:04-13:25	200.3	441	88.3	0.07[c]
06-30-88	AF-7	Loading Operator	6:04-13:25	197.1	441	86.9	0.11[c]
06-30-88	AF-9	Maintenance	6:03-12:22	200.9	379	76.1	0.34
06-30-88	AF-1	Loading Operator	6:00-13:30	203.1	450	91.4	0.11[c]
06-30-88	AF-12	QC lab (area)	6:09-13:30	200.7	441	88.5	0.25
06-30-88	AF-10	Loader (QC test)[d]	8:52-09:07	1000.0	15	15.0	0.21[c]
06-30-88	AF-15	QSR (QC tests)[d]	10:42-10:57	1000.0	15	15.0	0.43[c]
06-30-88	AF-20	Maint (draining)[d]	12:16-12:31	1000.0	15	15.0	6.86
06-30-88	AF-3	Loader (gauging)[d]	12:50-12:58	1000.0	8	8.0	0.40[c]

[a]Samples were not time-weighted to 8-hour concentrations.
[b]Sample result was less than the analytical limit of detection (0.01 mg/sample).
[c]Sample result was less than the analytical limit of quantitation (0.03 mg/sample).
[d]Short-term sample.

observed when small quantities of the drainage was periodically collected into a can at the discharge spout to check for any fuel. Neither gloves or respirator were worn during this activity.

While an inhalation exposure of 0.40 ppm 2-ME was measured for a loader operator when gauging a storage tank, the dermal exposure (though not measured) was observed to be considerable due to direct hand contact with a fuel-laden tape measure. Although the hands got visibly wet, no skin protection (i.e. gloves) was worn.

The analysis of QC samples also resulted in the relatively higher inhalation exposures to 2-ME. Again, the potential for skin contact when handling the fuel samples was high thereby resulting in dermal exposures. No personal protection equipment (i.e. respirators, gloves, impermeable coveralls) was worn during QC testing. Although not specifically evaluated in our survey, possible modification of current work practices and/or ventilation controls in the QC laboratory should be considered to reduce potential inhalation and dermal exposures to 2-ME.

CONCLUSIONS AND RECOMMENDATIONS

Generally, the government-owned Defense Fuel Support Point terminal in Cincinnati represents a clean fuel distribution operation with apparently well-maintained storage tanks and ancillary equipment. 2-ME is a minor component of one of the jet fuels (JP-4) handled. The potential exists for inhalation and dermal exposure to 2-ME, particularly during the following periodic activities: (1) sampling/gauging of fuel storage tanks, (2) sampling of fuel from incoming barges, (3) QC analysis, and (4) draining of water from storage tanks.

The monitoring results indicate that full-shift inhalation exposures to 2-ME are low (less than 0.34 ppm) probably because of the small percentage of 2-ME in the JP-4 fuel (0.10 to 0.15 percent) and the periodic nature of the activities that could result in high exposure potential. Higher short-term exposures, however, were measured during periodic activities including a measurement of 6.86 ppm on the maintenance worker during drainage of water from a JP-4 fuel storage tank. The long-term exposures compare to the 25 ppm OSHA PEL, the 5 ppm ACGIH TLV, and the "lowest feasible level" NIOSH REL.

Efforts to minimize exposures at the DFSP terminal should focus primarily on: (1) modifying work practices and/or ventilation conditions in the QC laboratory; and 2) providing personal protective equipment suitable for inhalation and dermal exposures (i.e. respirators and impermeable gloves) and encouraging their regular use during high exposure activities. (Note: NIOSH recommends that all practical engineering controls be applied prior to resorting to personal protective equipment for adequating reducing employee exposures in the workplace).

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